

longitudinal gain spatial hole burning at high current drive levels above threshold. By integrating first-order distributed Bragg reflectors at the end of such structures, surface emitting devices can be made to lase with both relatively high external differential quantum efficiencies as well as highly uniform near-field and guided-field intensity profiles. See, Lopez, et al., Appl. Phys. Lett., Vol. 73, No. 16, 19 Oct. 1998, pp. 2266-2268. However, the efficiency of such devices is limited due to the lossiness of the grating required to suppress the anti-symmetric mode.

The present invention addresses these limitations. It yields a high power surface emitting semiconductor laser that operates in a single mode with a single lobe far-field radiation profile without a penalty in device efficiency. Single lobe surface emission is achieved at high power levels with very high efficiency. The present claims in the application define the structural features that distinguish over the Botez, et al. patent 5,727,013, and other references of record, as explained below.

As an initial matter, applicants wish to note the nomenclature used in the claims. As is well known, and noted on page 1, lines 23-24 of the application, semiconductor lasers can be constructed to be either edge emitting or surface emitting. The present invention involves surface emitting lasers. However, such laser structures still have edges even though the intended laser emission does not occur at the edges. The remaining independent claims 13 and 27 both specify the structure of the semiconductor laser as including upper and lower faces, and edge faces. The upper and lower faces and the edge faces are thus distinctly specified and are separate structural features. It is at one of the upper or lower faces that surface emission of light occurs.

Claim 13 has been amended to specify that both of the edge faces are formed to be antireflective. This feature is described in the application at, e.g., page 5, lines 2-4

“... with both of the edge faces formed to be antireflective (such as with the use of an antireflective coating or by providing at the ends of the grating inclined facets overgrown with absorbing material)”; and shown in Figs. 10-13 and 15 and as described in the portions of the application discussing those figures.

The Office Action observed that the Botez, et al. patent has many of the structural features called for in Claim 13. The Office Action also indicated, with reference to Fig. 10 of the Botez, et al. patent that it included upper and lower edge faces 72 and 75, an edge face 72 which has high reflectivity and the other face 75 with lower reflectivity. The faces 72 and 75 of Fig. 10 of the Botez patent are not edge faces; rather they are the top and bottom surfaces of the laser structure which correspond to the upper and lower faces called for in Claim 13 (and in Claim 27). The semiconductor laser of Fig. 10 (a cross-sectional view) certainly has edge faces, but they are not shown in the cross-section of Fig. 10. The Botez patent 5,727,013 does not disclose the feature of both edge faces formed to be antireflective as now specified in Claim 13.

The Office Action further noted that the Botez, et al. patent includes a distributed feedback grating which comprises periodic alternating grating elements to provide optical feedback as a second order grating. The Action also asserted that the grating has spacing between adjacent grating elements at a position intermediate to the edge faces that corresponds to a selected phase shift in the grating. In fact, it is clearly seen in Fig. 10 of the Botez, et al. patent that the period of the alternating elements forming the grating is entirely uniform; there is no spacing in the grating that causes a phase shift of the period of the grating elements. This spacing between grating elements which causes a phase shift in the grating is shown, for example, in Figs. 6, 9, 10, 12, 13, 14, 15, and 16 of the present application. In

these figures, the phase shift is denoted as $\Delta\phi$. No such phase shift in the grating is shown in any of the figures of patent 5,727,013.

Thus, it is seen that the structure as defined in Claim 13 has several structural features which are neither disclosed nor suggested in the Botez et al. patent 5,727,013.

Similarly, Claim 27, which has not been amended, specifies that the grating has a spacing between adjacent grating elements at a position intermediate the edge faces that corresponds to a selected phase shift in the grating. No such phase shift in the grating is shown in the Botez patent 5,727,013. Further, Claim 27 also specifies passive distributed Bragg reflector gratings incorporated with the epitaxial structure adjacent the distributed feedback grating to reflect light back to the distributed feedback grating. The Botez patent 5,727,013 does not have distributed Bragg reflector gratings in addition to the distributed feedback grating.

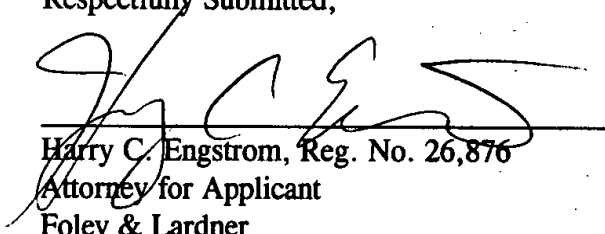
As noted above, the paper by Lopez, et al. shows a distributed feedback grating with distributed Bragg reflectors. However, the distributed feedback grating is uniform and there is no spacing between grating elements corresponding to a phase shift in the distributed feedback grating. The effect of the spacing in the grating to provide a grating phase shift, $\Delta\phi$, is discussed at various places in the present application, e.g., on pages 17-18, and the effect of the phase shift is illustrated in Figs. 23, 24, 25, 26 and 27. As seen from these figures, a phase shift $\Delta\phi$ at or about 180° is a preferred feature, and is specified in dependent Claims 24 and 26, dependent upon Claim 13, and in dependent Claims 38 and 43, ultimately dependent upon Claim 27. Other claims dependent upon Claims 13 and 27 add further preferred features of the invention. This phase shift in the grating is not suggested in the references.

Applicants note that the formal drawings that were submitted by applicants on December 26, 2000 did not include formal drawings for original Figs. 17-21, and renumbered

Figs. 22-27 as Figs. 18-22. Applicants will submit new formal drawings, including formal drawings for original Figs. 17-21 and renumbered Figs. 22-27, at such time as the application is indicated allowable.

For the foregoing reasons, it is submitted that the claims remaining in the application are neither shown or suggested in any of the references of record, and favorable action passing the application to allowance is respectfully solicited.

Respectfully Submitted,



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Copy of Claim Showing Amendments

13. (Amended) A surface emitting semiconductor laser comprising:

(a) a semiconductor substrate, an epitaxial structure on the substrate including a layer with an active region at which light emission occurs, upper and lower cladding layers surrounding the active region layer, upper and lower faces, edge faces, with both of the edge faces formed to be antireflective, and electrodes by which voltage can be applied across the epitaxial structure and the substrate; and

(b) a distributed feedback grating incorporated with the epitaxial structure comprising periodically alternating grating elements to provide optical feedback as a second order grating for a selected effective wavelength of light generation from the active region, the grating having a spacing between adjacent grating elements at a position intermediate the edge faces that corresponds to a selected phase shift in the grating, the grating formed and positioned to act upon the light generated in the active region to produce lasing action and emission of light from at least one of the upper and lower faces of the semiconductor laser.